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PRINCIPLES OF PHYSICAL SCIENCE FOUND IN PHYSICS TEXTBOOKS FOR THE SENIOR HIGH SCHOOL

by

Alfred John Brudzynski

submitted in partial fulfillment of the
requirements for the degree of
Master of Education
July, 1948

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CHAPTER I

SURVEY OF RELATED LITERATURE

Introduction

Everywhere we look we find an abundance of applications of scientific principles. Technological advances in means of communication, transportation, and in production during the last two decades have greatly affected man's way of living. During World War II use of atomic bombs, of jet propelled aircraft, of radar, and of medical discoveries have made man realize more than ever before the great part science plays in his very existence.

In order that growing children may have a better understanding and appreciation of those things about them which involve scientific principles, courses in science in all our schools should be more meaningful and beneficial.

In recent years the trend has been to construct courses of study in science at both the junior and senior high-school levels around the needs of the pupils. Teachers have been faced with the problem of how to teach funds of current information intended to be used only when the needs arise. Teachers have likewise been confronted with the problem of building up in those pupils the capacity

of determining their own needs for specific information and the understanding of where to get and how to apply that information.

In the report of the Commission on Secondary School Curriculum[1] five major needs of adolescent in the area of personal living are given. The needs for personal health, for self assurance, for a satisfying world picture and a workable philosophy of life, for a range of personal interests, and for esthetic satisfaction[2] are recommended to be used in setting up science course objectives. This commission further reports that not only should needs be met, but they should be met in such ways as to contribute to the progressive construction and refinement of the democratic way of life.[3]

Many surveys and research studies have been conducted in the past few years to set up a pattern which could be used as a guide for all types of courses of instruction. In the field of science education such surveys and research studies have not been as numerous as in other fields in spite of the evergrowing impor-

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[1]Progressive Education Association, Commission on Secondary School Curriculum, Science in General Education, New York: D. Appleton-Century Company, 1938.

[2]Ibid., p. 64.

[3]Ibid., pp. 454-455.

tance of its subject matter.

Wilbur L. Beauchamp[4] in his study indicated that there is no set formula for setting up and evaluating objectives in science teaching. He did, however, point out that the trends he found should be carefully considered by those who are continually attempting to improve their courses in secondary school sciences. Beauchamp found that since 1925 there have been revisions of 58 courses in general science, 45 courses in biology, 30 courses in chemistry, and 27 courses in physics. These findings can be viewed as the beginning of a new era in science teaching.

The National Society for the Study of Education[5] reported in 1932 that courses of instruction in physics and chemistry were dominated by college preparatory ideas. It further reports that "ideas of mastery of subject matter of the field as such and the disciplinary value of the subject expressed in terms of training in scientific method have governed

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[4]Wilbur L. Beauchamp, Instruction in Science, U.S. Office of Education, Bulletin, 1932, No. 17, National Survey of Secondary Education, Monograph No. 22, Washington: Government Printing Office, 1933.

[5]A Program For Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I, Bloomington, Illinois: Public School Publishing Company, 1932.

the thinking of teachers of chemistry and physics."[6] This report advocates the teaching of principles and generalizations as objectives. Classroom experiences must be provided to satisfy the aims of general education. "The major generalizations and associated scientific attitudes are seen as of such importance that understanding of them are made the objectives of science teaching".[7]

The Thayer Commission of the Progressive Education Association and the Thirty-First Yearbook Committee have greatly influenced science teachers to reorganize their courses around generalizations and principles. The Thayer Commission has also pointed out that the education of an individual is due to the effect on his whole behavior that has come from the experiences in which he has participated.[8]

Craig[9] postulated the following three criteria for the selection of objectives:

1. Certain objectives that are selected for elementary-school science should conform to those scientific conceptions (1) which

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[6]Ibid., p. 246.

[7]Ibid., p.44.

[8]Progressive Education Association, op. cit., p.42.

[9]Gerald S. Craig, Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School, Teachers College Contribution to Education, No. 276, pp. 12-13. New York: Teachers College, Columbia University, 1927.

understood greatly influence the thought reaction of the individual; (2) which have modified thinking in many fields.

2. Certain objectives that are selected for elementary-school science should conform to those goals (information, skills, and habits) in science that are important because of their function in establishing health, economy, and safety in private and public life.
3. Certain objectives that are selected for elementary-school science should conform to those facts, principles, generalizations, and hypotheses of science which are essential to the interpretation of natural phenomena which commonly challenge children.

"The principles and generalizations of science must, therefore, occupy considerable place in a program of general education, the aim of which is life enrichment."[10]

For the past fifteen years many research studies have been made in an attempt to bring about an accepted standard for all forms of instruction. In the field of science education, a few important surveys which have been recently conducted clearly indicate that there is a need for adoption of scientific principles and generalizations as objectives for courses in science.

SURVEY OF IMPORTANT RESEARCH STUDIES PERTAINING TO THE DETERMINATION OF PRINCIPLES AS OBJECTIVES OF SCIENCE TEACHING

The Fifth Yearbook of the Department of Super-

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[10] A Program for Teaching Science, op. cit., p. 43.

intendence of the National Education Association[11] advocated that the design and make-up of a course in science should be such that it enables the students to have experiences with the attainment of knowledge of scientific principles that are worthwhile from both a social and practical standpoint. The course should have provisions to allow for adequate drill in the application of life situations.

In the planning and organizing of a science course of study for the elementary grades, Craig[12] says that the teacher should not be concerned to any great extent with the training of children to become scientists, but rather the teacher should be deeply concerned with guiding pupils to become intelligent and law-abiding citizens. The understanding of phenomena which so often challenge and interest so many pupils can be accomplished by setting up objectives for a course in science that agree with the facts, principles, generalizations, and hypotheses of science.

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[11] The Junior High School Curriculum, Fifth Yearbook, Department of Superintendence, National Education Association, Washington, D.C.: Government Printing Office, 1927.

[12] Gerald S. Craig, op. cit., pp. 12-13.

Hackett[13] analyzed twelve textbooks in biology to find the amount of space that writers devote to the discussion of biological principles and their applications to problematic situations. The analysis showed that the amount of space devoted to such discussions ranged from forty-eight to twenty-three percent. The larger portion of the book in every case was factual and descriptive.

A study by Menzies[14] showed that in twelve college biology textbooks a range of 87 to 97.6 percent of the space available was devoted to principles and applications. The study further shows that little attention is given to the application of principles to problematic situations.

Heinemann[15] , in her study of principles in general science textbooks, discloses that principles in general science were given little consideration. Only ninety-three principles were

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[13]H.L. Hackett, "An Analysis of High School Text-books in Biology in Terms of Principles," Master's thesis, University of Chicago, School of Education, 1925.

[14]Jessie A. Menzies, "An Analysis of Ten General Biologies of College Level in Terms of Generalization and their Application to Life Situations. "Master's thesis, University of Chicago, School of Education, 1927.

[15]Ailsie M. Heinemann, "A Study of General Science Textbooks, "General Science Quarterly, XIII (November 1928), pp. 11-23.

found in twenty books analyzed. Heinemann further discloses that there is very little agreement among authors of textbooks as to which scientific principles are important in general science. She recommends that teachers should base their teaching on a small number of principles with many application instead of placing emphasis on a large number of principles with few applications. In her definition of a science principle Heinemann states, "a principle is a statement of relationship frequently causal in nature between two facts."[16]

In 1931 Wilbur[17] analyzed fourteen textbooks of general science used in the ninth grade. The definition of a principle and the criteria for the selection of principles that Wilbur used were the same as those Martin[18] used in his study. The following criteria[19]

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[16] Ibid., p. 11.

[17] Oliver B. Wilbur, "A Study of the Principles of Science Contained in General Science Textbooks Published Since the Beginning of the Year 1924." Unpublished Master's Thesis, University of Michigan 1931.

[18] W. Edgar Martin, "A Chronological Survey of Research Studies on Principles as objectives of Instruction in Science, "Science Education XXIV (February, 1945), p. 46.

[19] Ibid., p. 101.

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[16] Ibid., p. 11.

[17] Oliver B. Wilbur, "A Study of the Principles of Science Contained in General Science Textbooks Published Since the Beginning of the Year 1924" Unpublished Master's Thesis, University of Michigan 1931.

[18] Edgar Werlin, "A Chronological Survey of Research Studies on Principles as Objectives of Instruction in Science," Science Education XXIX (February, 1945), p. 46.

[19] Ibid., p. 101.

were used by both Wilbur and Martin:

1. It must be a comprehensive generalization which resumes the widest possible range of facts within the domain of facts with which it is directly concerned. The facts resumed in the generalization must denote:
   a. Objects and/or events and the relation between them.
   b. Properties.
2. It must be scientifically true. To satisfy a criterion:
   a. It must be verifiable; i.e. it must be stated so that it suggests, directly or indirectly, a definite operation of observations or experiments whereby its truth value can be tested or verified.
   b. It must be consistent with the body of accepted scientific knowledge, and except for a few limiting or singular exceptions, with all the data (facts) relevant to it.

Wilbur tabulated the principles and submitted them to subject-matter specialists in biology, chemistry, geology, and physics for validation in terms of the criteria and for revision of inaccurate and unsatisfactory statements. After the principles were returned from the specialists they were then given to ten teachers of science who were requested to indicate which of these are necessary, or undesirable in a course of general science. It was found that from all fourteen textbooks only eighteen of the 170 principles were given, even in part, in principle form, in more than half of the textbooks analyzed. The ten instructors who

evaluated them felt that only five of the eighteen principles were necessary.[20]

Lucas[21] made an analysis of current chemistry textbooks for secondary schools. He found that the space in those books given to principles and problems involving their application is thirty per cent.

In Koppenaal's analysis[22] of current physics books, a similar study to that of Lucas, it is shown that the more recent textbooks devote about 28 per-cent of the total word space available to discussion of principles and of problematic situations demanding their applications. The largest number of principles discussed in any one textbook is forty-three and the total number of principles given in the textbooks analyzed was about sixty.

Robertson[23] conducted an investigation to

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[20]Wilbur, op. cit., p. 47.

[21]Loren T. Lucas, "Analysis of Chemistry Texts in Terms of Principles." Master's thesis, University of Chicago, Department of Education, 1932.

[22]Peter Koppenaal, "An Analysis of High-School Physics Textbooks in Terms of Principles." Master's thesis, University of Chicago, Department of Education, 1932.

[23]Martin L. Robertson, "The Selection of Science Principles Suitable as Goals of Instruction in Elementary School." Science Education, XIX (February, 1935), 1-4 XIX (April, 1935), 65-70.

determine the principles of science suitable as goals of instruction in the elementary grades. A list of major and minor principles of science was developed from ten research studies that had been previously made. After the list was compiled it was submitted to a group of twenty experts in the field of science for evaluation as to the suitability of the principles to be included in an elementary science course of instruction. A list of 243 principles was reduced to 113 after the experts evaluated them.

At the University of Chicago, investigations were made under the direction of Downing[24] to find what principles are most needed in the solution of everyday problems. These investigations were also made to determine the order of importance of principles. From these, Downing made up a total list of 96 principles necessary in chemistry, physics, and biology and gave their relative order of importance.

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[24] Elliot R. Downing, Teaching Science in the Schools, pp. 39-48. Chicago: University of Chicago Press, 1925.

While at Columbia University in 1935, Pruitt[25] conducted an investigation in the field of chemistry. He listed those generalizations and concepts which have the most value to man in his interpretation of his environment. As part of his investigation Pruitt analyzed three college-entrance examinations; one year's issues of the Atlantic Monthly, The Forum, and Harper's Magazine; about 50,000 pages of material in five books of sociology; 12 issues each of Popular Science Monthly, Scientific American, and Science News Letter; copies of eight well-known newspapers for an entire year; and finally, sixty-five textbooks in the various science fields. With the aid of the same criteria for developing a principle which Robertson used in his study, 135 chemical concepts and generalizations were formulated and were arranged in the approximate order of their importance.

Martin[26] in his chronological survey of research studies of principles as objectives in a

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[25]Clarence Martin Pruitt, "An Analysis, Evaluation, and Synthesis of Subject-Matter Concepts and Generalizations in Chemistry." Doctor's dissertation, Teachers College, Columbia University, 1935. Third Digest of Investigations in the Teaching of Science by Francis D. Curtis. Philadelphia: P. Blakiston's Sons and Company, Inc., 1939, pp. 153-163.

[26]W. Edgar Martin, "A Chronological Survey of Research Studies on Principles as Objectives of Instruction in Science," Science Education, XXIX (February, 1945), pp. 45-52.

course of instruction in science reported 29 research studies. He gives a description of 18 studies. Included in these, however, were 11 contributing studies making the total of 29. Martin's[27] own study in the determination of the principles of the biological sciences, brought the total up to 30.

Martin divided his study into two phases, namely, the inductive and the deductive. The purpose of the inductive phase was to obtain a tentative list of the important principles of the biological sciences while the purpose of the deductive phase was to determine only those principles of his master list which are of importance as objectives in science program taught for general education. In the analysis, three junior-college textbooks, three high-school textbooks, a survey series of biological sciences for the general reader, and reports of five research studies which satisfied the criteria were used. A list of statements was made up and then checked by three specialists in biology. After the list was returned from the specialists it consisted of 300 major principles and 236 minor principles.

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[27]W. Edgar Martin, "A Determination of the Principles of the Biological Sciences of Importance for General Education," Science Education, XXIX (March, 1945), pp. 100-105; XXIX (April-May, 1945), pp. 152-163.

At the University of Michigan in 1941 Wise[28] conducted a study to determine what principles of the physical sciences are most important for general education. The first step of this study consisted in making up a tentative list of principles. The second step was determining the relative importance of principles by frequency of their applications in the solution of problems that are encountered in general living. The evaluation of the results of contributing studies by Craig, Curtis, Davis, Heiss, Muller, Nelson, Newland, Partridge, Robertson, and Weiser was the third step. The final step was a synthesis of the results of the contributing studies.

The criteria[29] that Wise used in the study to determine a principles were:

1. To be a principles a statement must be a comprehensive generalization describing some fundamental process, constant mode of behavior, or property relating to natural phenomena.

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[28]Harold E. Wise, "A Determination of the Relative Importance of Principles of Physical Science for General Education." Unpublished Doctor's dissertation, University of Michigan, 1941. Science Education, XXV (December, 1941), pp. 371-379; XXVI (January, 1942), pp. 8-12; XXVII (February, 1943), pp. 36-40; XXVII (September-October, 1943), pp. 67-76.

[29]Ibid., p. 371.

2. It must be true without exception within limitations specifically stated.
3. It must be capable of illustration.
4. It must not be a definition.

In his final results, Wise gave a list of 264 principles of physical science in their relative order of importance. The highest ranking half of the principles included 108 principles of physics, 28 principles of chemistry, and 6 principles of geology.

In four communities of Massachusetts, Fleish[30] conducted a survey in grades VII through XII to determine those principles which should be used as objectives in the teaching of general-science courses. After making up a list of sixty principles based on questions submitted by pupils, Fleish analyzed ten general-science textbooks to determine how much space the authors devote to the sixty principles. Although many textbooks did include a large number of her principles, the authors did not state them in clear and concise language.

At the University of Michigan in 1946 Jones[31]

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[30]Sylvia Fleish, "The Formulation of the Science Principles that Should Become the Objectives of General Science Teaching in the Junior High School." Unpublished Master's thesis, Boston University, 1945.

[31]Ruth V. Jones, "A Study of the Principles of Science Found in Nine Grade Textbooks of General Science," Unpublished Master's thesis, University of Michigan, 1946.

carried on an investigation to determine the principles of science found in seven ninth-grade textbooks in general science. The conclusion drawn by Jones was that there is very little, if any, agreement on the number and selection of scientific principles included in the seven textbooks she analyzed.

Keeslar[32] carried on an investigation to find out the extent to which instructional films in science education contribute to objectives of general education. In the selected films, made for instruction in science, he found that little effort is made to teach scientific principles, scientific method, or scientific attitudes.

In his doctoral dissertation, Blanchet[33] used the physical science principles prepared by Wise and the biological science principles prepared by Martin for assigning subject-matter topics to principles. Blanchet's criteria for a principle, therefore, were the same as the work of both Wise and Martin.

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[32]Orean Keeslar, "Contributions of Instructional Films to the Teaching of High School Science," Science Education, XXX (March, 1946) pp. 82-88, XXX (April, 1946, pp. 132-136).

[33]Waldo Emerson Blanchet, "A Basis for the Selection of Course Content for Survey Courses in the Natural Sciences." Unpublished Doctor's dissertation, University of Michigan, 1946.

Blanchet's work was divided into four major parts. The first part consisted in determining the principles of science most suitable as goals for survey courses in the natural sciences at the junior-college level. In the second part he set out to determine the extent to which the principles are included in textbooks published for use in survey courses in the natural sciences. The third part consisted of determining the subject-matter topics found in textbooks for use in the natural sciences, as a source of informational materials with which to develop understanding of the principles. Finally, in his fourth part he determined student opinion concerning the relative values of topics which they had studied in survey courses in the natural sciences.

With the co-operation of specialists in the teaching of sciences and of college teachers of science he was able to accomplish his first part. The principles of science most suitable as goals for survey courses[34] were chosen on the basis of the combined judgement of these individuals.

To carry out the second part of his investigation it was necessary to set up a group of

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[34]Ibid., p. 35.

criteria for selecting principles from the textbooks. The methods which the various authors used in giving principles varied widely. Consequently, Blanchet used the following criteria to decide whether statements were of a particular principle or not:

1. If it expressed completely the idea in the original statement of the principle.
2. If, though it did not state all of the elements of the principle, it was referred to by the author or authors as being the said principle.
3. If it unmistakeably implied the principle and could be reworded so that the principle was stated.
4. If, though it did not state the principle in full, it could be combined justifiably with another statement in the same paragraph or secion, which together stated the principle or could be reworded to do so.

In the preparation of the composite topical outline of the third part of his work, Blanchet submitted outlines to three specialists in the teaching of science. These specialists examined the outlines critically to determine if the position of each topic in each outline was defensible. Secondly, these outlines were checked so as to be free from repetition and duplication. In the last step of this third part the frequency of the topics of the composite outline was determined.

The fourth and last part of this extensive investigation consisted of assigning a selected sampling of the topics of the composite outline to those principles of science which are very important goals of instruction in survey courses in science. Copies of the composite outline and the assigned principles were submitted to three specialists in the teaching of science to check the defensibility of the assignments of principles to the topics. The results of this fourth part of the investigation show that Wise's 272 physical principle were assigned to 1171 topics while Martin's 300 principles of the biological sciences were assigned to a total of 970 topics. The conclusion Blanchet drew from this fourth part was that there exists a wide diversity in material-content in science textbooks and that although diversified, there exists suitable materials for teaching of the understanding of the principles of the natural sciences.

SURVEY OF LITERATURE PERTAINING TO THE DETERMINATION OF THE EFFECTIVENESS OF PRINCIPLES IN TERMS OF RETENTION OF LEARNING

In three Ohio High Schools, Frutchey[35] con-

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[35] F.P. Frutchey, "Retention in High School Chemistry," Educational Research Bulletin, Ohio State University, XVI (February, 1937), pp. 34-37.

ducted experiments to determine if principles are retained longer than facts. Five pre-tests were given to measure certain knowledge, abilities, and skills in chemistry. Another test was given nine months later to ascertain the gains. A year after the course had been completed still another test was given to measure the retention of the subject matter covered in the course.

The results of this experiment show that factual material is not retained as long as are principles. In the application of principles, both boys and girls retained the same percentages of their progress made in the course.

At Ohio University Tyler[36] found that factual material is forgotten most quickly. In the results of zoology course examinations, it was learned that material of general information is more permanent. The ability to apply zoological principles to entirely new situations during a fifteen month period is not seriously lost by students. In his conclusion, Tyler recommends that examinations which are developed by college

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[36]Ralph W. Tyler, "Permanence of Learning," Journal of Higher Education, IV (April, 1933) pp. 203-204.

teachers should be built around materials which have more permanent value in college education.

Zeigler[37] in his study of general science, showed that only those principles which students meet and encounter in their daily life situations are retained. Although science knowledge is practical and useful as well as valuable, he concludes that there is too much emphasis placed on facts which will be forgotten in a short time.

In a survey which Johnson[38] carried out to learn the extent of pupil's retention of information connected with botany, it was found that those students who have the most botanical information at the time of completing the course are likely to retain more after periods of fifteen and twenty-seven months than students with less botanical information. The rate of loss in the ability to retain the learned information was very rapid during the period between three and fifteen months after completion of the course. After the fifteen months, the loss in retention showed a gradual decline.

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[37]Robert T. Zeigler, "A Study of Fact Retention in General Sciences," Science Education, XXVI (February, 1943), pp. 83-84.

[38]Palmer O. Johnson, "The Permanence of Learning in Elementary Botany," The Journal of Educational Psychology, XXI (January, 1930), pp. 37-47.

Wert[39], in an investigation on the retention of course growth, shows that the loss of retention is greater with information which is less specific. With the lapsing of time, students show some gain in the ability to apply principles of zoology to new situations.

Using the findings of Frutchey, Tyler, Johnson and others as a basis for a study, Reek[40] found that from the standpoint of retention of learning, it is very important to teach science principles and that unrelated factual material is highly unsatisfactory if retention is to be considered as an important factor.

SUMMARY OF RESEARCH STUDIES

A review of the foregoing surveys and investigations definitely points to the fact that scientific principles and generalizations are justifiably recognized as objectives of science instruction for general education.

Frutchey, Zeigler, Johnson, Wert, and Tyler all give evidence that the teaching of fac-

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[39] James E. Wert, "Twin Examination Assumptions," Journal of Higher Education, VIII (March, 1937), pp. 136-140.

[40] Doris Lucille Reek, "A Study of the principles of Science in Four Series of Textbook of Elementary Science." Unpublished Master's thesis, University of Michigan, 1943.

tual material is no longer justified as an end in itself.

Reports of the Thayer Commission and the Thirty-First Yearbook, along with the research studies conducted at Columbia University, New York University, University of Minnesota, Ohio State University, University of Chicago, and the University of Michigan, justify the developing of functional understanding of scientific principles as a major objective of science teaching.

The investigations conducted by Martin and Wise have made valuable contributions in the statement of scientific principles. They did not attempt, however, to determine principles suitable for various grade levels.

PROBLEM OF THE INVESTIGATION

The purpose of this investigation is to determine what principles of physical science are found in four textbooks of physics at the senior-high school level published or revised since 1942. Criteria for choosing statements of principles were established by fifteen teachers in a Seminar in Science Education, Boston University, 1946-47.

STATEMENT OF THE PROBLEM

The problem of this investigation is to select from four textbooks of physics for the senior high-school level, statements which can be justifiably assigned to the principles of physical science compiled by Wise.

SCOPE AND LIMITATION OF THIS INVESTIGATION

This investigation is limited to the analysis of four textbooks of physics written specifically for the senior high school and with a copyright date of 1942 or later.

Wise's list of 272 physical principles will be used in the assignment of statements to the principles. Only those principles will be selected that appear to the investigator to conform to the criteria established for this investigation even though the possibility exists that there may be other principles suitable as goals of physics instruction at the senior high school.

CHAPTER II

THE INVESTIGATION

RESTATEMENT OF THE PROBLEM

The problem of this investigation is to select from four textbooks of physics for the senior high-school level, statements of principles which can be justifiably assigned to the principles of physical science compiled by Wise.

TECHNIQUES EMPLOYED

Selection of Textbooks for Analysis

For the purpose of this investigation the following criteria were adopted by a group of fifteen science teachers in a Seminar in Science Education at Boston University, 1946-47, and used as the basis for the selection of high-school textbooks analyzed:

1. Must be available for use at the time the study is started.
2. Must have been published by a reputable publishing house.
3. Must have been published or revised since 1942.
4. Must be representative of textbooks of physics used in high schools.

Four books which met the above criteria are:

Book 1. Elements of Physics, Robert W. Fuller, Raymond B. Brownlee, and D. Lee Baker, Boston: Allyn and Bacon, 1946, pp. 1-831.

Book 2. Experiences in Physics, Lester R. Willard, and Charles S. Winter, Boston: Ginn and Company, 1943, pp. 1-640.

Book 3. New Elementary Physics, Robert A. Millikan, Henry G. Gale, and James P. Coyle, Boston: Ginn and Company, 1944, pp. 1-626.

Book 4. Physics for Secondary Schools, Oscar M. Stewart, and Burton L. Cushing, Boston: Ginn and Company, 1946, pp. 1-755.

The above assigned numbers hereafter are used in identifying the textbooks.

Criteria for a Principle as Found in Textbooks of High-School Physics

Wise[1] in his doctoral dissertation written in 1941, gave a list of 264 principles of physical science in their relative order of importance for the purpose of general education for grades I-XIV inclusive. Eight additional principles were not included in the list because they did not adequately meet the criteria established.

Since Wise's extensive study included a comprehensive list of physical principles which were determined by defensible research techniques, this investigator feels that the list is the best available. This investigation, therefore, is based on the same scientific principles or generalizations that Wise listed.

Blanchet[2] in his doctoral dissertation at

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[1]Wise, Harold E., op. cit.

[2]Blanchet, Waldo Emerson, op. cit.

the University of Michigan developed four criteria which he used in the selection of statements of principles from textbooks intended for use at the junior-college level. At the high-school level, however, Blanchet's criteria were found to be inadequate. Because principles are usually introduced in simple form at the lower grade levels and then developed more and more through the junior-college, it seems reasonable to assume that some statements can be justifiably assigned to senior high-school level while at the junior-college the statement might fall short of meeting all the requirements. For this reason, it was found necessary to establish a new set of criteria to be used for this investigation.

The fifteen teachers of science in the 1946-1947 Seminar in Science Education at Boston University saw fit to modify Wise's criteria so that they could be used in the selection of statements of principles at the senior high-school level. The modified criteria were as follows:

> A statement is considered to be that of a particular principle:
>
> 1. If it expresses completely the idea embodied in the original statement of the principle in Wise's list; or

2. If, though it does not state all of the elements of the principle, it is implied by the author or authors as being the said principle; or
3. If it unmistakably implies the principle and can be reworded so that the principle is stated; or
4. If, though it does not state the principle in full, it can be combined justifiably with another statement in the same paragraph or section, which, if together state the principle.

Method of Analysis of Textbooks for Principles

The first step of this investigation consisted of analyzing the tables of contents of each book studied. It was found that a reasonable degree of similarity existed.

Book 1 had:

Unit I	Matter and Molecules
Unit II	Behavior of Fluids
Unit III	Mechanics of Solids
Unit IV	Heat
Unit V	Sound
Unit VI	Light
Unit VII	Magnetism and Electricty
Unit VIII	Land and Air Travel

Book 2 had:

Unit I	What You Should Know about Matter
Unit II	What You Should Know about Forces
Unit III	What You Should Know about Heat
Unit IV	What You Should Know about Sound
Unit V	What You Should Know about Light
Unit VI	What You Should Know about Magnetism and Electricty

Book 3 had:

Unit I	The Properties of Fluids
Unit II	The Laws of Force and Motion

Unit III	Work and Heat
Unit IV	Electricity and Magnetism
Unit V	Wave Motion and Sound
Unit VI	Light
Unit VII	Electronics and Invisible Radiation

Book 4 had:

Unit I	Mechanics and Properties of Matter
Unit II	Heat
Unit III	Magnetism and Electricity
Unit IV	Wave in Matter: Sound
Unit V	Light Waves
Unit VI	Electrical Emissions and Waves; Atomic Transformations

Because of the similarity of units in each of the four books, Wise's principles were grouped under seven topical headings:

1. Matter and Molecules
2. Mechanics of Fluids and Solids
3. Sound
4. Light
5. Heat
6. Magnetism and Electricity
7. Atoms, Atomic Transformations and Electrical Emissions

The principles were then written on a three by five inch card and placed under proper topical headings. In order to facilitate the handling of the cards, seven pockets, were made of thin cardboard and pasted in seven different places on the inside of a two-flap file folder $8\frac{1}{2}$" x 11". In these pockets were placed each group of cards with the principles written on them.

After this preliminary work was completed the task of analyzing each book page by page was

undertaken. When a statement of a principle which met the criteria established was found it was first underlined in the textbook. The book and page numbers were then recorded on three by five inch file cards. This procedure was continued until all four books were completely analyzed.

Coefficient of Reliability for the Selection of Principles from the Textbooks

Because of the wide variations in human judgement, the investigator determined the "coefficient of reliability" in the selection of principles from textbooks. Two months after the first analysis one hundred pages selected at random from one of the textbooks were rechecked for principles.

The randomly selected 100 pages from Book 1 were found to have 25 principles which were common to both analyses. In the first analysis only 25 principles were found while in the second, three additional statement of principles appeared making a total of 28. Substituting in the formula, "coefficient of reliability" equals $\frac{A}{A+B+C}$ where A is the number of principles common to both analysis; B is the number of principles found to appear only in the list resulting from the first

analysis, and C is the number of principles found to appear only in the list of the second analysis the value of .893 was obtained.

Table I, which follows, shows the book number and the total number of books in which the designated principles occurred in the four books analyzed.

TABLE I

THE NUMBER OF HIGH-SCHOOL TEXTBOOKS OF PHYSICS IN WHICH THE DESIGNATED PRINCIPLES WERE FOUND

Principles	Books in which principles occurred				
	1	2	3	4	Total
MATTER AND MOLECULES					
*All substances are made up of small particles called molecules which are alike in the same substance (except for variations in molecular weight due to isotopes but different in different substances.	x	x		x	3
The average speed of molecules increases with the temperature and pressure.				x	1
Matter may be transformed into energy and energy into matter, the sum total matter plus energy remains constant.		x	x	x	3
All matter is made up of protons, neutrons, and electrons.	x	x		x	3

*Table 1 is read thus: The principle "All substances are made up of small particles called molecules which are alike in the same substances (except for variations in molecular weight due to isotopes) but different in different substance" was found at least once in each of the textbooks 1, 2, and 4, a total of three different books, and was assigned to the topic, Matter and Molecules under which it was found in the textbooks.

Principles	Books in which principles occurred				
	1	2	3	4	Total
All substances are made up of small particles called molecules which are alike in the same substance (except for variations in molecular weight due to isotopes) but different in different substances.	x	x		x	3
The average speed of molecules increases with the temperature and pressure.				x	1
Matter may be transformed into energy and energy into matter. The sum total matter plus energy remains constant.		x	x	x	3
All matter is made up of protons, neutrons, and electrons.	x	x		x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
MECHANICS OF FLUIDS AND SOLIDS					
The rate of evaporation of a liquid varies with the temperature, area of exposed surface, and saturation and circulation of the gas in contact with the liquid.	x	x	x	x	4
A fluid has a tendency to move from a region of higher pressure to one of lower pressure; the greater the difference, the faster the movement.		x			1
When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and vice versa.	x		x	x	3
Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass.	x	x	x	x	4

TABLE I
(CONTINUED)

Principles	Books in which principles are found				
	1	2	3	4	Total
MECHANICS OF FLUIDS AND SOLIDS					
The rate of evaporations of a liquid varies with the temperature, area of exposed surface, and saturation and circulation of the gas in contact with the liquid.	x	x	x	x	4
A fluid has a tendency to move from a region of higher pressure to one of lower pressure; the greater the difference, the faster the movement.		x			1
When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and vice versa.	x		x	x	3
Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass.	x	x	x	x	4

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The pressure in a fluid in the open is equal to the weight of the fluid above a unit area including the point at which the pressure is taken; it therefore varies as to the depth and average density of the fluid.	x	x	x	x	4
Energy can never be created or destroyed; it can be changed from one form to another with exact equivalence.	x	x	x	x	4
If the same pressure is maintained the volume of a gas is varied directly as the absolute temperature.	x			x	2
The natural movements of air, water, and solids on the earth are due chiefly to gravity plus rotation of the earth.	x				1
The higher the temperature of air the greater the amount of moisture required to saturate it.			x	x	2

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
A body immersed or floating in a fluid is buoyed up by a force equal to the weight of the fluid displaced.	x	x	x	x	4
The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction.	x	x	x	x	4
Bodies in rotation tend to fly out in a straight line which is tangent to the area of rotation.	x	x	x	x	4
Condensation will occur when a vapor is at its saturation point if centers of condensation are available and if heat is withdrawn.	x	x	x	x	4
The volume of an ideal gas varies inversely with the pressure upon it, providing the temperature remains constant.	x	x	x	x	4
A gas always tends to expand throughout the whole space available.			x	x	2

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
In the lever the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.	x	x	x	x	4
The atmospheric pressure decreases as the altitude increases.	x	x	x	x	4
The energy which a body possesses on account of its motion is called kinetic energy and is proportional to its mass and the square of its velocity.	x	x	x	x	4
When the resultant of all the forces acting on a body is zero, the body will stay at rest if at rest, or it will keep in uniform motion in a straight line if it is in motion.	x			x	2
Centrifugal force is directly proportional to the square of the velocity, to the mass, and inversely proportional to the radius of rotation.	x		x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The atmospheric pressure decreases with increasing water vapor content, other things being equal.	x				1
The acceleration of a body is proportional to the resultant force acting on that body and is in the direction of that force.	x		x	x	3
Sliding friction is dependent upon the nature and condition of the rubbing surfaces, proportional to the force pressing the surfaces together and independent of the area of contact.	x				1
In the inclined plane, weight times height equals acting force times length, providing friction is neglected and the force is parallel to the plane.	x	x	x	x	4

Principles	Books in which principles occurred				
	1	2	3	4	Total
The atmosphere exerts pressure decreases with increasing water vapor content, other things being equal.	x				1
The acceleration of a body is proportional to the resultant force acting on that body and is in the direction of that force.	x		x	x	3
Sliding friction is dependent upon the nature and condition of the rubbing surfaces, proportional to the force pressing the surfaces together and independent of the area of contact.	x				1
In the inclined plane, weight times height equals acting force times length, providing friction is neglected and the force is parallel to the plane.	x	x	x	x	4

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
When pressure is applied to any area of a liquid in a closed container, it is transmitted in exactly the same intensity to every area of the container in contact with the liquid.	x	x	x	x	4
Any homogeneous body of liquid free to take its own position, will seek a position in which all exposed surfaces lie on the same horizontal plane.			x	x	2
As the velocity of flow through a constricted area increases, the pressure diminishes.	x	x	x		3
If the volume of a confined body of gas is kept constant, the pressure is proportional to the absolute temperature.	x	x		x	3

Principles	Books in which principles occurred				
	1	2	3	4	Total
When pressure is applied to any area of a liquid in a closed container, it is transmitted in exactly the same intensity to every area of the container in contact with the liquid.	x	x	x	x	4
Any homogeneous body of liquid free to take its own position, will seek a position in which all exposed surfaces lie on the same horizontal plane.			x	x	2
As the velocity of flow through a constricted area increases, the pressure diminishes.	x	x	x		3
If the volume of a confined body of gas is kept constant, the pressure is proportional to the absolute temperature.	x	x		x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
When one body exerts a force on a second body, the second body exerts an equal and opposite force on the first.	x	x	x	x	4
The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that was done in order to bring it into the specified condition.	x	x	x	x	4
The height to which a liquid rises in a capillary tube is directly proportional to the surface tension of the liquid and inversely proportional to the density of the liquid and to the radius of the tube.	x				1
The distortion of an elastic body is proportional to the force applied provided the elastic limit is not exceeded.	x	x	x	x	4

Principles	Books in which principles occurred				
	1	2	3	4	Total
When one body exerts a force on a second body, the second body exerts an equal and opposite force on the first.	x	x	x	x	4
The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that was done in order to bring it into the specified condition.	x	x	x	x	4
The helper to which a light rises in a capillary tube is directly proportional to the surface tension of the liquid and inversely proportional to the density of the liquid and to the radius of the tube.	x				1
The distortion of an elastic body is proportional to the forces applied provided the elastic limit is not exceeded.	x	x	x	x	4

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
When two forces act upon the same object, the resultant is the diagonal of a parallelogram whose sides represent the direction and magnitude of the two forces. A single force represented by the diagonal may be resolved into two forces represented by the sides of the parallelogram.	x		x	x	3
At any point on the earth's surface all bodies fall with a constant acceleration which is independent of the mass or size of the body if air resistance be neglected.	x		x	x	3
The amount of momentum possessed by an object is proportional to its mass and its velocity.	x	x	x	x	4
The pressure at a point in any fluid is the same in all directions.	x	x	x	x	4

TABLE I
(CONTINUED)

	Books in which principles occurred				
	1	2	3	4	Total
The period of a pendulum swinging through short arcs is independent of the weight of the bob but varies directly as the square root of the length and inversely as the square root of the acceleration of gravity.	x		x	x	3
Fluids have no elastic limits for compression.	x				1
All liquids are compressible but only to a light degree.			x		1
The speed gained by a body with a constant acceleration is equal to the product of the acceleration and the time.	x		x	x	3
The distance a body travels, starting from rest with a constant acceleration, is one-half the acceleration times the square of the time.	x		x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The free surface of a liquid contracts to the smallest possible area due to surface tension.	x		x	x	3
When forces act in the same directions, the resultant is their algebraic sum.	x		x	x	3
SOUND					
Sound is produced by vibrating matter and transmitted by matter.	x	x	x	x	4
The higher the pitch of the note, the more rapid the vibrations of the producing body.	x	x	x	x	4
The velocity of sound is directly proportional to the square root of the elasticity modulus and inversely proportional to the square root of the density of the transmitting medium.	x				1

Principles	Books in which principle occurred				
	1	2	3	4	Total
The free surface of a liquid conforms to the smallest possible area due to surface tension.	x		x	x	3
When forces act in two directions, the resultant is their algebraic sum.	x		x	x	3
Sound is produced by vibrating matter and transmitted by matter.	x	x	x	x	4
The higher the pitch of the note, the more rapid the vibrations of the producing body.	x	x	x	x	4
The velocity of sound is directly proportional to the square root of the elasticity modulus and inversely proportional to the square root of the density of the transmitting medium.	x				1

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
Musical tones are produced when a vibrating body sends out regular vibrations to the ear while only noises are produced when the vibrating body sends out irregular vibrations to the ear.			x		1
The quality of a musical tone is determined by the pitch and intensity of the different simple tones or harmonics into which it may be resolved.			x	x	2
The loudness of a sound depends upon the energy of the sound waves and, if propagated in all directions, decreases inversely as the square of the distance from the source.	x	x	x		3
Sound waves or other energy impulses may set up vibrations in a body the amplitude of which is increased if the impulses are exactly timed to correspond to any one of the natural periods of vibrations of the body.	x	x	x	x	4

Principles	Books in which principles occurred				
	1	2	3	4	Total
Musical tones are produced when a vibrating body sends out regular vibrations to the ear while duty noises are produced when the vibrating body sends out irregular vibrations to the ear.			X		1
The quality of a musical tone is determined by the pitch and intensity of the different simple tones or harmonics into which it may be resolved.			X	X	2
The loudness of a sound depends upon the energy of the sound waves and, if propagated in all directions, decreases inversely as the square of the distance from the source.	X		X		2
Sound waves or other energy impulses may set up vibrations in a body the amplitude of which is increased if the impulses are exactly timed to correspond to any one of the natural periods of vibrations of the body.	X	X	X	X	4

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
Sound waves are reflected in a direction such that the angle of incidence is equal to the angle of reflection.	x				1
Two sound waves of the same or nearly the same frequency will destructively interfere with each other when the condensations of the one coincide with the rarefactions of the other provided that the directions of propagations are the same.	x		x	x	3
Harmonious musical intervals correspond to very simple frequency ratios.	x		x	x	3
The frequency of the vibration of a stretched string is inversely proportional to its length, diameter, and square root of its density, and directly proportional to the square root of the stretching force.	x		x	x	3

	Books in which principle occurred				
	1	2	3	4	Total
Principles					
Sound waves are reflected in a direction such that the angle of incidence is equal to the angle of reflection.	x				1
Two sound waves of the same or nearly the same frequency will destructively interfere with each other when the condensations of the one coincide with the rarefactions of the other provided that the directions of propagations are the same.	x		x	x	3
Harmonious musical intervals correspond to very simple frequency ratios.	x		x	x	3
The frequency of the vibration of a stretched string is inversely proportional to the length, directly proportional to the square root of its density, and directly proportional to the square root of the absolute tension.	x		x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The speed of sound increases with an increase in temperature of the medium conducting it.	x	x	x	x	4
Waves travel in straight lines while passing through a homogeneous or uniform medium.	x				1
The velocity of a wave is equal to the product of its frequency and wave length.	x	x	x	x	4
When a sounding body is moving toward or away from an observer the apparent pitch will be higher or lower, respectively, than the true pitch of the sound emitted.	x		x	x	3
LIGHT					
When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal and when they pass obliquely from a dense to a rarer medium, they are bent away from the normal.	x	x	x	x	4

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The speed of sound increases with an increase in temperature of the medium conducting it.	x	x	x	x	4
Waves travel in straight lines while passing through a homogeneous or uniform medium.	x				1
The velocity of a wave is equal to the product of its frequency and wave length.	x	x	x	x	4
When a sounding body is moving toward or away from an observer the apparent pitch will be higher or lower, respectively, than the true pitch of the sound emitted.	x		x	x	3
When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal and when they pass obliquely from a dense to a rarer medium, they are bent away from the normal.	x	x	x	x	4

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
If a beam of light falls upon an irregular surface the rays of light are scattered in all directions.	x	x	x	x	4
Parallel light rays may be converged or focused by convex lenses or concave mirrors, diverged by concave lenses or convex mirrors.				x	1
The dispersion of white light into a spectrum by a prism is caused by unequal refraction of different wave lengths of light.	x	x	x	x	4
Incandescent solids and liquids emit all wave lengths of light and give a continuous spectrum.			x	x	2
The dimensions of an image produced by a lens or a mirror are to the dimensions of the object as their respective distances from the lens or mirror are to each other.	x		x	x	3

Principles	Books in which principles occurred				
	1	2	3	4	Total
If a beam of light falls upon an irregular surface the rays of light are scattered in all directions.	x	x	x	x	4
Parallel light rays may be converged or focused by convex lenses or concave mirrors, diverged by concave lenses or convex mirrors.				x	1
The dispersion of white light into a spectrum by a prism is caused by unequal refraction of different rays (wave lengths of light.	x	x	x	x	4
Incandescent solids and liquids emit all rays (wavelengths of light and give a continuous spectrum.			x	x	2
The dimensions of an image produced by a lens or a mirror are to the dimensions of the object as their respective distances from the lens or mirror are to each other.	x		x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The sum of the reciprocals of the conjugate lengths of a lens or mirror equals the reciprocal of the principle focal length.			x	x	2
The curvature of a wave front will be changed a given amount by a lens; namely, 1/F.			x		1
When light is reflected, the angle of incidence is equal to the angle of reflection.	x	x	x	x	4
The color of objects depend upon what light rays they transmit, absorb or reflect.	x	x	x	x	4
The speed of light in any given substance bears a constant ratio to the speed of light in air.			x		1
Luminous vapors and gases emit only certain kinds of light producing bright line spectra.	x	x		x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The intensity of illumination decreases as the square of the distance from a point source.	x	x	x	x	4
The darker the color of a surface the better it absorbs light.				x	1
When light is incident upon a medium in which it will travel faster and when the angle of incidence is greater than the critical angle, it is totally reflected.	x	x	x	x	4
An image appears to be as far back of a plane mirror as the object is in front of the mirror and is reversed.	x	x	x	x	4
When light rays are absorbed, some of the light energy is transformed into heat energy.			x		1

Principles	Books in which principles occurred				
	1	2	3	4	Total
The intensity of illumination decreases as the squares of the distance from a point source.	x	x	x	x	4
The nature and color of a surface vibe better it absorbs light.			x		1
When light is incident upon a medium in which it will travel faster and when the angle of incidence is greater than the critical angle, it is totally reflected.	x	x	x	x	4
An image appears to be as far back of a plane mirror as the object is in front of the mirror and is reversed.	x	x	x	x	4
Some light rays are absorbed, some of the light energy is transformed into heat energy.			x		1

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
When white light passes through a substance that absorbs some waves and not others, certain bands of color are missing with the production of an absorption spectrum.			x	x	2
When a body which emits a bright line spectrum is moving toward or away from the observer, the lines are shifted toward the short or long wave length end of the spectrum, respectively.			x		1
In a plane mirror a line running from any point on the object to the image of that point is perpendicular to the mirror.	x	x	x	x	4
All rays passing through the center of curvature of a mirror are reflected upon themselves.			x		1

	Book in which pertinent material appears				
	1	2	3	4	Total
When white light passes through a substance that absorbs some waves and not others, certain bands of color are missing with the production of an absorption spectrum.			x	x	2
When a body which emits a bright line spectrum is moving toward or away from the observer, the lines are shifted toward the short or long wave length end of the spectrum, respectively.			x		1
In a plane mirror a line reading from any point on the object to the image of that point is perpendicular to the mirror.	x	x	x	x	4
All rays passing through the center of curvature of a mirror are reflected upon themselves.			x		1

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
When parallel light strikes a concave spherical mirror, the rays, after reflection, pass directly through the principal focus only if the area of the mirror is small compared to its radius of curvature.		x			1
A beam of light may become plane polarized as a result of any circumstance which results in the suppression of one of the rectilinear components of the vibration without affecting the components at right angles to it.				x	1
HEAT					
Solids are liquefied and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance, is specific and equals that given off in the reverse process.		x	x	x	3

Principles	Number of solid particles observed				
	1	2	3	4	Total
When parallel light strikes a concave spherical mirror, one type, after reflection, pass directly through the principal focus only if the area of the mirror is small compared to its radius of curvature.		x			1
A beam of light may become plane polarized as a result of any circumstance which results in the suppression of one of the rectilinear components of the vibration without affecting the components at right angles to it.				x	1
Solids are liquefied and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance, is specific and equals that given off in the reverse process.		x	x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
When two bodies of different temperature are in contact, there is a continuous transference of heat energy, the rate of which is directly proportional to the difference of temperature.	x	x			2
Most bodies expand on heating and contract on cooling the amount of change depending upon the change in temperature.	x	x	x	x	4
Heat is liberated when a gas is compressed, and is absorbed when a gas expands.		x		x	2
Whenever an opaque object intercepts radiant energy traveling in a particular direction, a shadow is cast behind the object.		x			1
Dark, rough or unpolished surfaces absorb or radiate energy more effectively then light, smooth or polished surfaces.	x	x			2

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TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
When two bodies of different temperature are in contact, there is a continuous transference of heat energy, the rate of which is directly proportional to the difference of temperature.	x	x			2
Most bodies expand on heating and contract on cooling the amount of change depending upon the change in temperature.	x	x	x	x	4
Heat is liberated when a gas is compressed, and is absorbed when a gas expands.		x	x	x	2
Whenever an opaque object intercepts radiant energy traveling in a certain direction, a shadow is cast behind the object.			x		1
Dark, rough, or unpolished surfaces absorb or radiate energy more effectively than light, smooth or polished surfaces.	x		x		2

TABLE I
(Continued)

Principles	Books in which principles occurred				
	1	2	3	4	Total
When a gas expands, heat energy is converted into mechanical energy.		x		x	2
Heat is conducted by the transfer of kinetic energy from molecule to molecule.	x	x	x	x	4
The atmosphere of the earth tends to prevent the heat of the earth's surface from escaping, and the earth begins to cool only when the amount of heat lost during the night exceeds that gained during the day.	x		x		2
The amount of heat which a constant mass of a liquid or solid requires when its temperature rises a given amount is identical with the amount it gives off when its temperature falls by that amount.	x		x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The amount of heat developed in doing work against friction is proportional to the amount of work thus expended.		x			1
Every pure liquid has its own specific boiling and freezing point.	x				1
The boiling point of any solution becomes lower as the pressure is decreased and higher as the pressure is increased.	x	x	x	x	4
The total change in length of a metal bar is equal to its co-efficient of linear expansion times the original length times the change of temperature in degree C.	x	x	x	x	4
Substances which expand upon solidifying have their melting points lowered by pressure, those which contract upon solidifying have their melting points raised by pressure.		x	x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The pressure of a dissolved substance will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than pure water.	x		x	x	3
Freezing point depression and boiling point elevation are proportional to the concentration of the solution.		x			1
The pressure of a saturated vapor is constant at a given temperature, and increases with an increase of temperature.				x	1
ELECTRICITY AND MAGNETISM					
An electric charge in motion produces a magnetic field about the conductor, its direction being tangential to any circle drawn about the conductor in a plane perpendicular to it.			x		1

	Books in which principles occurred				
	1	2	3	4	Total
	x		x	x	3
		x			1
				x	1
			x		1

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The amount of heat produced by an electric current is proportional to the resistance, the square of the current and the time of flow.	x		x	x	3
An electric current will flow in an external circuit when two metals of unlike chemical activity are acted upon by a conducting solution, the more active metal being charged negatively.	x	x	x	x	4
Electrons will always flow from one point to another along a conductor if this transfer releases energy.	x			x	2
Like electrical charges repel and unlike electrical charges attract.	x		x	x	3
An e.m.f. is induced in a circuit whenever there is a change in the number of the lines of magnetic force passing through the circuit.	x	x	x	x	4

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
Charges on a conductor tend to stay on the surface and to be greatest on the sharp edges and points.	x	x	x	x	4
An induced current always has such a direction that its magnetic field tends to oppose the motion by which the current was produced.	x	x	x	x	4
An electrical current flowing in a conductor is directly proportional to the potential difference and inversely proportional to the resistance.	x	x	x	x	4
All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy.	x		x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
An electric current may be produced three ways, by rubbing or friction, chemical action and the use of a magnetic field.				x	1
Electrostatic induction is the separation of charges on a conductor through the influence of a neighboring charge.	x		x	x	3
Like magnetic poles always repel each other and unlike magnetic poles always attract each other.	x	x	x	x	4
The mass of any substance set free by electrolysis is proportional to the current flowing and the time of flow; if the quantity of electricity is kept constant, the masses of the various substances set free are proportional to their electro-chemical equivalents.	x				1

Principles	Books in which principles occurred				
	1	2	3	4	Total
An electric current may be produced three ways, by rubbing or friction, chemical action and the use of a magnetic field.				x	1
Electrostatic induction is the separation of charges on a conductor through the influence of a neighboring charge.	x		x	x	3
Like magnetic poles always repel each other and unlike magnetic poles always attract each other.	x	x	x	x	4
The mass of any substance set free by electrolysis is proportional to the current flowing and the time of flow; if the quantity of electricity is kept constant, the masses of the various substances set free are proportional to their electro-chemical equivalents.	x				1

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
Positively charged ions of metals may be deposited on the cathode, as atoms, when a direct current is sent through an electrolyte.	x		x		2
The magnitude of an induced e.m.f. is proportional to the rate at which the number of lines of magnetic force change and to the number of turns of wire in the coil.	x	x	x	x	4
Electric power is directly proportional to the product of the potential difference and the current.	x	x	x	x	4
The resistance of a metallic conductor depends on the kind of material from which the conductor is made, varies directly with the length, inversely with the cross sectional area, and increases as the temperature increases.	x	x	x	x	4

Principles	Books in which principles occurred				
	1	2	3	4	Total
	x		x		2
	x	x	x	x	4
	x	x	x	x	4
	x	x	x	x	4

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
Whenever a high frequency oscillating current produces in a field around it oscillating electric and magnetic fields, energy in the form of an electro-magnetic wave is transmitted through space.	x	x	x	x	4
The force of attraction or repulsion between two magnetic poles varies directly as the product of the pole strengths and inversely as the square of the distance between the poles.	x		x		2
By means of high frequency generators or vacuum-tube oscillators, sustained or continuous oscillations can be produced in a condenser circuit. Their intensity is made to vary with audio-frequency currents in a transmitter circuit to produce radio waves.				x	1

Principles	Cases in which principles occurred				
	1	2	3	4	Total

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
In an uncharged body there are as many protons as electrons and the charges neutralize each other while a deficiency of electrons produces a plus charge on a body and an excess of electrons produces a negative charge.	x	x	x	x	4
When a current-carrying wire is placed in a magnetic field, there is a force acting on the wire tending to push it at right angles to the direction of the lines of force between the magnetic poles, providing the wire is not parallel to the field.			x	x	2
Pieces of iron, steel, cobalts, or nickel may become magnetized by induction when placed within a magnetic field.	x	x	x	x	4

Principles	Books in which principles occurred				
	1	2	3	4	Total

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
In a transformer the ratio between voltages is the same as that between the number of turns.	x	x	x	x	4
Electrolytes dissolved in water exist partially or completely as electrically charged particles called ions.	x			x	2
In a series circuit the current is the same in all parts, the resistance of the whole is the sum of the resistance of the parts, and the voltage loss of the whole is the sum of the voltage losses of the parts.	x		x	x	3
In a parallel circuit the total current is the sum of the separate currents, the voltage loss is the sum for each branch, and the total resistance is less than the resistance of any one branch.	x		x	x	3

Principles	Books in which principles occurred				
	1	2	3	4	Total
In a transformer the ratio between voltages is the same as that between the number of turns.	x	x	x	x	4
Electrolytes dissolved in water exist partially or completely as electrically charged particles called ions.	x			x	2
In a series circuit the current is the same in all parts, the resistance of the whole is the sum of the resistances of the parts, and the voltage loss of the whole is the sum of the voltage losses of the parts.	x		x	x	3
In a parallel circuit the total current is the sum of the separate currents, the voltage loss is the sum for each branch, and the total resistance is less than the resistance of any one branch.	x		x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
Energy in kilowatt hour is equal to the product of amperes, volts, and time (in hours) divided by one thousand.	x		x	x	3
A magnet always has two poles and is surrounded by a field of force.	x	x	x	x	4
Gases conduct electric currents only when ionized.				x	1
Electrons are emitted from any sufficiently hot body.	x	x	x	x	4
ATOMS, ATOMIC TRANSFORMATION, RADIOACTIVITY, AND ELECTRICAL EMISSIONS					
Elements are made up of small particles of matter called atoms which are alike in the same element (except for occasional differences in atomic weight; i.e. isotopes) but different in different elements.			x	x	2

Principles	Books in which principles occurred				
	1	2	3	4	Total
Energy in always near is equal to the product of amperes, volts, and time (in hours) divided by one thousand.	x		x	x	3
A magnet always has two poles and is surrounded by a field of force.	x	x	x	x	4
Gases conduct electricity when ionized.				x	1
Electrons are emitted from any sufficiently hot body.	x	x	x	x	4
ATOMS, ATOMIC STRUCTURE, RADIOACTIVITY, AND ELECTRICAL EMISSIONS					
Elements are made up of small particles of matter called atoms which are alike in the same element (except for occasional difference in atomic weight; i.e. isotopes) but different in different elements.			x	x	2

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
Atoms of all elements are made up of protons, neutrons and electrons, and differences between atoms of different elements are due to the number of protons and neutrons in the nucleus and to the configuration of electrons surrounding the nucleus.	x			x	2
Radioactivity is independent of all physical conditions; heat, cold, pressure, and chemical state.			x		1
The atoms of all radioactive elements are constantly disentergrating by giving off various rays (alpha, beta, and gamma) and forming helium and other elements.			x	x	2
Radioactive emission involves nuclear changes.	x				1

Principles	Scores in which principles occurred				
	1	2	3	4	Total
Abuse of all sensitive one made up of protons, neutrons and electron. and different atoms of different elements run due to the number of protons and neutrons in the nucleus and to the configuration of electrons surrounding the nucleus.	x			x	2
Radioactivity is independent of all physical conditions; heat, cold, pressure, and chemical state.			x		1
The atoms of all radioactive elements are constantly disintegrating by giving off various rays (alpha, beta, and gamma) and forming helium and other elements.			x	x	2
Most decays emit electron involves nuclear change.	x				1

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons.	x		x		2
The mass of an atom is concentrated almost entirely in the nucleus.			x	x	2
Protons and neutrons only are found in the nucleus of an atom.	x			x	2
When a stream of high speed electrons strike a body, the atoms of that body emit x-rays.	x		x	x	3
In a tube which contains gas at low pressure subject to an intensely electric field, cathode rays, streams of electrons, move away from the negatively charged terminal at high speed.	x		x	x	3

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	1	2	3	4	Total
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The mass of an atom is concentrated almost entirely in the nucleus.			x	x	2
Protons and neutrons only are found in the nucleus of an atom.	x			x	2
When a stream of high speed electrons strike a body, the atoms of that body emit x-rays.	x		x	x	3
In a tube when containing gas at low pressure subject to an intensely electric field, cathode rays, streams of electrons, move away from the negatively charged terminal at high speed.	x		x	x	3

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
Atoms may be broken down by bombarding the nucleus with high speed particles such as protons, alpha particles, or neutrons.	x			x	2
Atoms or molecules may lose electrons when struck by high speed electrons or ions.	x			x	2

Findings. The four textbooks analyzed contained a total of 147 principles of physical science. Some principles were found in only one book while others were found in all four. Still others were found in two and three books.

Table II, which follows, gives the number of principles for each topic found in the four books analyzed. In addition, the number of principles for each book and the average number per book are given.

TABLE I
(CONTINUED)

Principles	Books in which principles occurred				
	1	2	3	4	Total
Atoms may be broken down by bombarding the nucleus with high speed particles such as protons, alpha particles, or neutrons.	x			x	2
Atoms or molecules may lose electrons when struck by high speed electrons or ions.	x			x	2

TABLE II

NUMBER OF DIFFERENT PRINCIPLES BY TOPICS FOUND IN FOUR TEXTBOOKS OF HIGH-SCHOOL PHYSICS

Topic	Total number of different principles	Book Number				Average number of principles per book
		1	2	3	4	
*Matter and Molecules	4	2	3	1	4	2.5
Mechanics of Fluids and Solids	43	38	22	34	35	32.3
Sound	15	13	6	12	10	10.1
Light	23	11	11	18	17	14.2
Heat	18	11	15	12	15	13.2
Electricity and Magnetism	32	27	15	26	28	24.0
Atoms, Atomic Transformations, and Electrical Emissions	12	8	0	7	9	6.0
Total	147	110	72	110	118	101.0

*Table II is read thus: Of the total number of different principles for Matter and Molecules, 4, Book 1 contained 2, Book 2 contained 3, etc., and the average number of principles for the four textbooks was 2.5.

TABLE II

NUMBER OF DIFFERENT PRINCIPLES BY TOPICS FOUND IN FOUR TEXTBOOKS OF HIGH-SCHOOL PHYSICS

Topic	Total number of different principles	Book Number				Average number of principles per book
		1	2	3	4	
Matter and Molecules	4	2	3	1	4	2.5
Mechanics of Fluids and Solids	43	28	22	34	36	28.5
Sound	16	13	6	12	10	10.1
Light	23	11	11	18	17	14.2
Heat.	18	11	15	12	15	13.2
Electricity and Magnetism	32	27	19	26	23	24.0
Atoms, Atomic Transformations, and Electrical Emissions	12	8	0	7	9	6.0
Total	147	110	72	110	118	101.0

*Table II is read thus: Of the total number of different principles for Matter and Molecules, 4, Book 1 contained 2, Book 2 contained 3, etc., and the average number of principles for the four textbooks was 2.5.

Findings. Under five of the seven topics, Book 2 was found to have fewer statements of principles than any of the other three books. Under the topic Atoms, Atomic Transformation, and Electrical Emission no statements of principles were found. Book 4, on the other hand, yielded totals for five of the seven topical groupings higher than any of the other three books. Book 1 was found to have the greatest number of principles under the topic Mechanics of Fluid and Solids.

In the average number of principles for the four books 2.5 was found under the topical heading Matter and Molecules as one extreme, and 32.3 under Mechanics of Fluids and Solids as the other extreme.

Table III, which follows, gives the total number of principles and the percent of the total found for each of the four books. The average number of principles and the average percent of the number of principles.

TABLE III

TOTAL NUMBER OF DIFFERENT PRINCIPLES FOUND IN FOUR TEXTBOOKS OF HIGH-SCHOOL PHYSICS, NUMBER FOUND IN EACH BOOK AND PERCENTAGE OF THE TOTAL FOUND

Total Number of Different Principles	Number of Different Principles in Book				Average
	1	2	3	4	
*147	110	72	110	118	102.5
Percent of	75	49	75	81	70.0

*Table III is read thus: Of the total number of 147 different principles found in all four books, 110 or 75 percent were found in Book 1, 72 or 49 percent in Book 2, etc., for an average of 102.5 per book, or an average of 70 percent of the total 147 principles.

Findings. Book 2 was found to have only 72 statements of principles of the 147 found in all four books. This number expressed in percent of the total is only 49.

Book 4 had 118 statements which conformed adequately to the criteria of a statement of principle, or 81 percent of the total.

In terms of averages the total number of principles was 102.5 and the percent was 70.

CHAPTER III

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Statement of the Problem

The problem of this investigation was to select from four textbooks of physics for the senior high-school level, statements which can be justifiably assigned to the principles of physical science compiled by Wise.

SUMMARY OF THE TECHNIQUES EMPLOYED

The assignment of statements of principles found in four physics textbooks was started by first copying the list of principles compiled by Wise on file cards three by five inches. The cards were then grouped under seven topical headings, and placed in pockets that were pasted on the insides of a two-flap file folder eight by eleven inches. An eighth pocket was pasted and used only for those principles which did not apply to physics.

In the page by page analysis of four books, the page number was recorded on the file card when a statement of principle was found. In addition, each statement was underlined in the book it appeared. This method was followed until all the books were completely analyzed.

SUMMARY OF THE FINDINGS

Book 4 was found to have the greatest number of statements of principles. Of the combined 147 found in all the books, 118 or 81 percent were found in Book 2. Books 2 and 3 were both found to have 110 or 75 percent of the total.

The average number of principles per book grouped by topics were:

Matter and Molecules	2.5
Mechanics of Fluids and Solids	32.3
Sound	10.1
Light	14.2
Heat	13.2
Electricity and Magnetism	24.0
Atoms, Atomic Transformation and Electric Emission	6.0

Lastly, the number of principles per book was 101.

CONCLUSIONS

Since the development of the understanding of principles of physical science is considered by this investigator to be an important factor in teaching a course in physics at the senior high-school level, it seems reasonable to assume that textbook writers should focus their thinking on principles. As borne

out by the tables of this investigation, a fairly wide range in thinking exists along these lines. It is encouraging to note, however, that the more recent books contain a larger number of principles than the older ones. The book with a revision date of 1943 had only 49 percent of the total statements of principles found, while the books revised in 1946 yielded 75 and 81 percents.

The topic of Electricity and Magnetism has occupied a larger amount of book space than any of the other six topics in all four books analyzed. The number of principles found under that topic, on the other hand, is an average of 24 per book as compared to 32.3 per book under the topic Mechanics of Fluids and Solids. The importance of the topic has been recognized, but the number and kind of principles seem apparently to be regarded as unimportant.

RECOMMENDATIONS

Textbooks in physics for the senior high school should be written to help in the development of the understanding of the principles given in Wise's list. They should likewise be organized to incorporate important applications of these principles.

Those people who are now writing textbooks in physics or comtemplate doing so should include or

plan to include sufficient materials to develop adequately the principles given in Wise's list. If the problem of book space is encountered it is recommended that those principles which are given at the top of the list be first considered.

After a period of about five years from today, a study similar to this one should be undertaken to determine whether physics textbook writers have included more principles in their books than those analyzed for this investigation. It is hoped that such an investigation will show a greater number than found by this one.

Since the possibility exists that five years from now Wise's list of principles may need additions it is, therefore, further recommended that a study similar to that of Wise be conducted so that the "Master" list of principle is up-to-date.

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